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RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

THE STATIC-PRESSURE ERROR OF A WING AIRSPEED INSTALLATION
OF THE MCDONNELL XF-88 AIRPLANE IN DIVES

TO TRANSONIC SPEEDS

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THE STATIC-PRESSURE ERROR OF A WING AIRSPEED INSTALLATION
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SUMMARY

Measurements were made, in dives to transonic speeds, of the static-pressure position error at a distance of one chord ahead of the wing tip of the McDonnell XF-88 airplane. The airplane incorporates a wing which is swept back 35° along the 0.25-chord line and utilizes a 65-series airfoil with a 9-percent-thick section perpendicular to the 0.25-chord line. The section in the stream direction is approximately 8 percent thick. Data up to a Mach number of about 0.97 were obtained within an airplane normal-force-coefficient range from about 0.05 to about 0.68. Data at Mach numbers above about 0.97 were obtained within an airplane normal-force-coefficient range from about 0.05 to about 0.38.

Results of the measurements indicate that the static-pressure error, within the accuracy of measurement, is negligible from a Mach number of 0.65 to a Mach number of about 0.97. With a further increase in Mach number, the static-pressure error increases rapidly; at the highest Mach number attained in these tests (about $M = 1.038$), the error increases to about 8 percent of the impact pressure. Above a Mach number of about 0.975, the recorded Mach number remains substantially constant with increasing true Mach number; the installation is of no value between a Mach number of about 0.975 and at least 1.038, as the true Mach number cannot be obtained from the recorded Mach number in this range.

Previously published data have shown that at 0.96 chord ahead of the wing tip of the straight-wing X-1 airplanes, a rapid rise of position error started at a Mach number of about 0.8. In the case of the XF-88 airplane, this rise of position error was delayed, presumably by the sweep of the wing, to a Mach number of about 0.97.

INTRODUCTION

Measurements of the static-pressure error of wing and fuselage airspeed installations on the X-1 airplanes in transonic flight (reference 1) indicated that wing-tip airspeed installations on straight-wing airplanes will, at transonic and supersonic speeds, be subject to static-pressure errors which vary extremely with Mach number. No measurements have yet been reported, however, of the static-pressure position error of a wing-tip airspeed installation on a swept-wing airplane in the transonic speed range.

The NACA was requested by the McDonnell Aircraft Corporation to make a high Mach number calibration of an airspeed installation of the swept-wing XF-88 airplane as a part of the airplane performance investigation. Measurements of the static-pressure position error of the wing-tip-boom airspeed installation were made in four dives to transonic speeds by the radar tracking method of reference 2. The results of these measurements are reported herein, and are felt to be of general interest to the problem of designing an airspeed installation for a transonic airplane.

SYMBOLS

p'	recorded static pressure
p	true static pressure
Δp	static-pressure position error, $p' - p$
M'	recorded Mach number
M	Mach number corrected for static-pressure error
q_c	true impact pressure
n	airplane normal acceleration
W	airplane weight
q	dynamic pressure $0.7\rho M^2$
S	airplane wing area
C_{NA}	airplane normal-force coefficient $\left(\frac{nW}{qS}\right)$

D maximum fuselage diameter
c wing-tip chord
d₁ pitot static-head diameter
d₂ wing-tip-boom diameter

AIRPLANE DESCRIPTION

The test vehicle,
The McDonnell XF-88 airplane, is a swept-wing airplane powered by two Westinghouse 24-C turbojet engines. The airplane incorporates a wing which is swept back 35° along the 0.25-chord line and utilizes a 65-series airfoil with a 9-percent-thick section perpendicular to the 0.25-chord line. The section in the stream direction is approximately 8 percent thick.

INSTRUMENTATION

Airplane instrumentation.— The pitot static head used in these tests was a standard Kollsman high-speed head. A drawing of the head is given in figure 1. The pitot static head was located at one chord ahead of the airplane wing tip. A plan view of the airplane showing the location of the pitot static head is given in figure 2.

Measurements of static pressure and impact pressure were recorded on a standard NACA airspeed recorder. For purposes of checking, approximately, the airplane normal-force-coefficient range in these tests, values of airplane normal acceleration were obtained from an indicating accelerometer mounted on a flight photo panel located near the airplane center of gravity. The timing sequence of the pressure recorder was transmitted on the airplane VHF channel to the ground station.

Ground instrumentation.— The NACA ground radar recording system used in these tests is described in detail in reference 1.

ACCURACIES

A detailed estimation of the accuracy with which an airspeed calibration can be obtained by the radar tracking method as practiced at Muroc is presented in reference 1. For the tests reported herein,

dives from pressure altitudes of about 37,000 feet to about 22,000 feet, the accuracies that can be expected are as follows:

Radar.— A maximum error in the determination of the static-pressure error of about ± 0.046 inch of mercury at a pressure altitude of 37,000 feet to about ± 0.083 inch of mercury at a pressure altitude of 22,000 feet.

Airplane.— A maximum error of ± 0.07 inch of mercury in the measurement of pressure altitude and of ± 0.025 inch of mercury in the measurement of airspeed.

Lag.— Estimates of the time lag in the airspeed system were made, using the methods described in reference 3. For the first two dives, NACA recording instruments, solely, were connected to the airspeed system, and it was indicated that lag effects on the system were negligibly small for the rates of descent attained in these dives. For the last two dives, an indicating Mach meter was connected to the airspeed system in addition to the NACA recording instrument with the result that lag effects were measurable for the rates of descent attained in the latter dives. Corrections for lag effects on both static-pressure and impact-pressure measurements were made to data from the latter dives, by use of the methods presented in reference 3. The data corrected for measurable lag effects are shown in figure 3 by unflagged symbols.

Over-all accuracy.— From a consideration of the foregoing, the over-all accuracy of measurement for these tests was ± 2 percent of the true impact pressure.

TEST RESULTS AND DISCUSSION

The static-pressure error of the wing-tip-boom airspeed installation is presented in figure 3 as the variation of the coefficient $\Delta p/q_c$ with Mach number. It is indicated that, within the accuracy of measurement, the static-pressure error is negligible from a Mach number of 0.65 to a Mach number of about 0.97. With a further increase in Mach number, the static-pressure error increases rapidly; at the highest Mach number attained in these tests (about $M = 1.038$), the error increases to about 8 percent of the impact pressure. The effect of the rapid increase in the static-pressure error upon the airspeed installation is shown in figure 4, where the variation of the recorded Mach number with corrected Mach number is presented. It is indicated that above a Mach number of about 0.975, the recorded Mach number remains substantially constant with increasing true Mach number. The installation apparently is of no value between a Mach number of about 0.975 and at least 1.038, as the true Mach number cannot be obtained from the recorded Mach number in this range.

Measurements of the static-pressure error made at 0.96 chord ahead of the wing tip of the straight-wing X-1 airplanes (reference 1) (incorporating 65-series airfoils of 8- and 10-percent thickness) showed that a rapid rise in the static-pressure error started at a Mach number of about 0.80. The results for the 35° swept-wing XF-88 airplane (fig. 3) show that the static-pressure error ahead of the wing tip does not start to rise until a Mach number of about 0.97 is reached. This indicates the effect of sweep in delaying the rapid rise of the static-pressure error in the same manner that other compressibility effects are delayed by sweep.

Data up to a Mach number of about 0.97 were obtained within an airplane normal-force-coefficient range from about 0.05 to about 0.68. Data at Mach numbers above 0.97 were obtained within an airplane normal-force-coefficient range from about 0.05 to about 0.38. No measurable variation of the static-pressure error with airplane normal-force coefficient was apparent in these tests.

CONCLUDING REMARKS

Measurements made of the static-pressure error at a point one chord ahead of the wing tip of the McDonnell sweptback-wing XF-88 airplane, in dives to transonic speeds, indicate:

The static-pressure error, within the accuracy of measurement, is negligible from a Mach number of 0.65 to a Mach number of about 0.97. With a further increase in Mach number, the static-pressure error increases rapidly; at the highest Mach number attained in these tests (about $M = 1.038$) the error increases to about 8 percent of the impact pressure. Above a Mach number of about 0.975, the recorded Mach number remains substantially constant with increasing true Mach number; the installation is of no value between a Mach number of about 0.975 and at least 1.038, as the true Mach number cannot be obtained from the recorded Mach number in this range.

The sweep of the XF-88 wing is apparently effective in delaying the rapid rise of the static-pressure error to a Mach number of about 0.97; previously published data of static-pressure-error measurements ahead of the wing tip of the X-1 airplanes (incorporating 65-series airfoils with 8- and 10-percent thickness) show a rapid rise in the static-pressure error at a Mach number of about 0.80.

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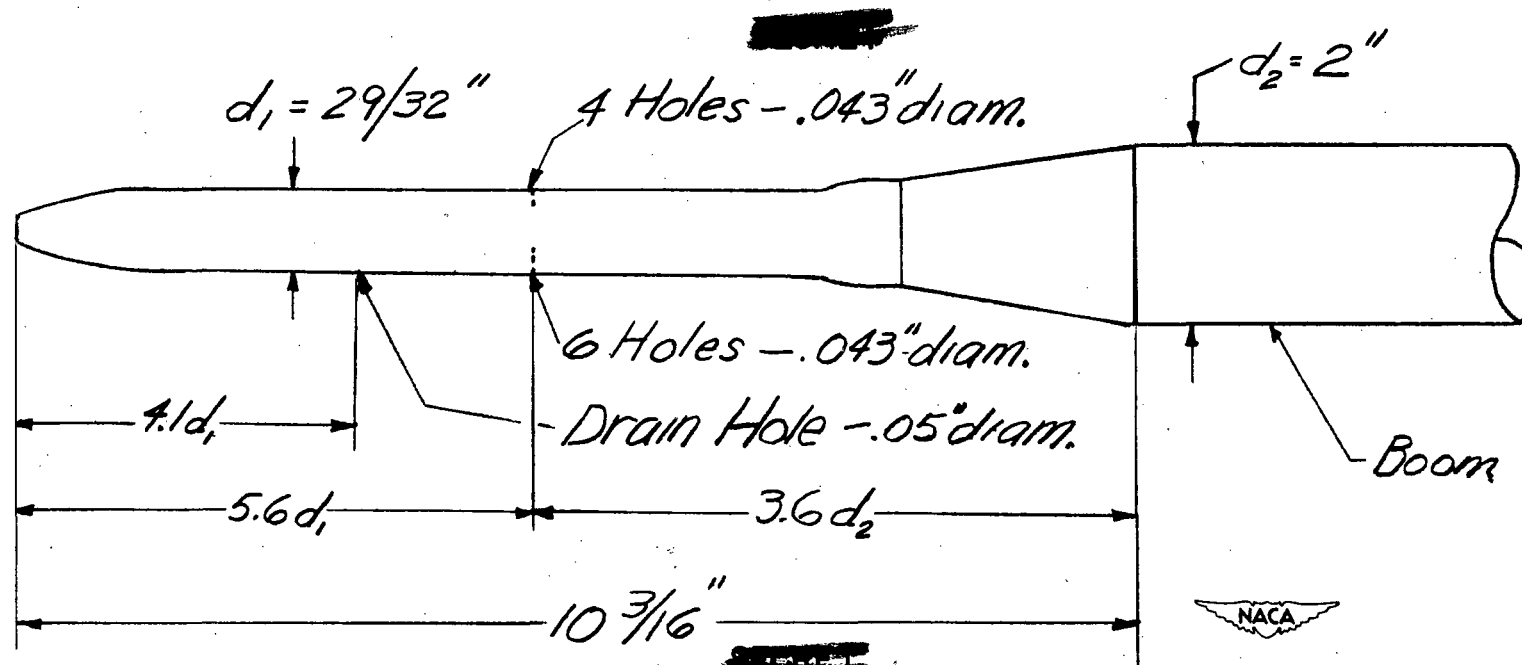


Figure 1.- Kollsman high-speed pitot-static head used on XF-88 airplane.

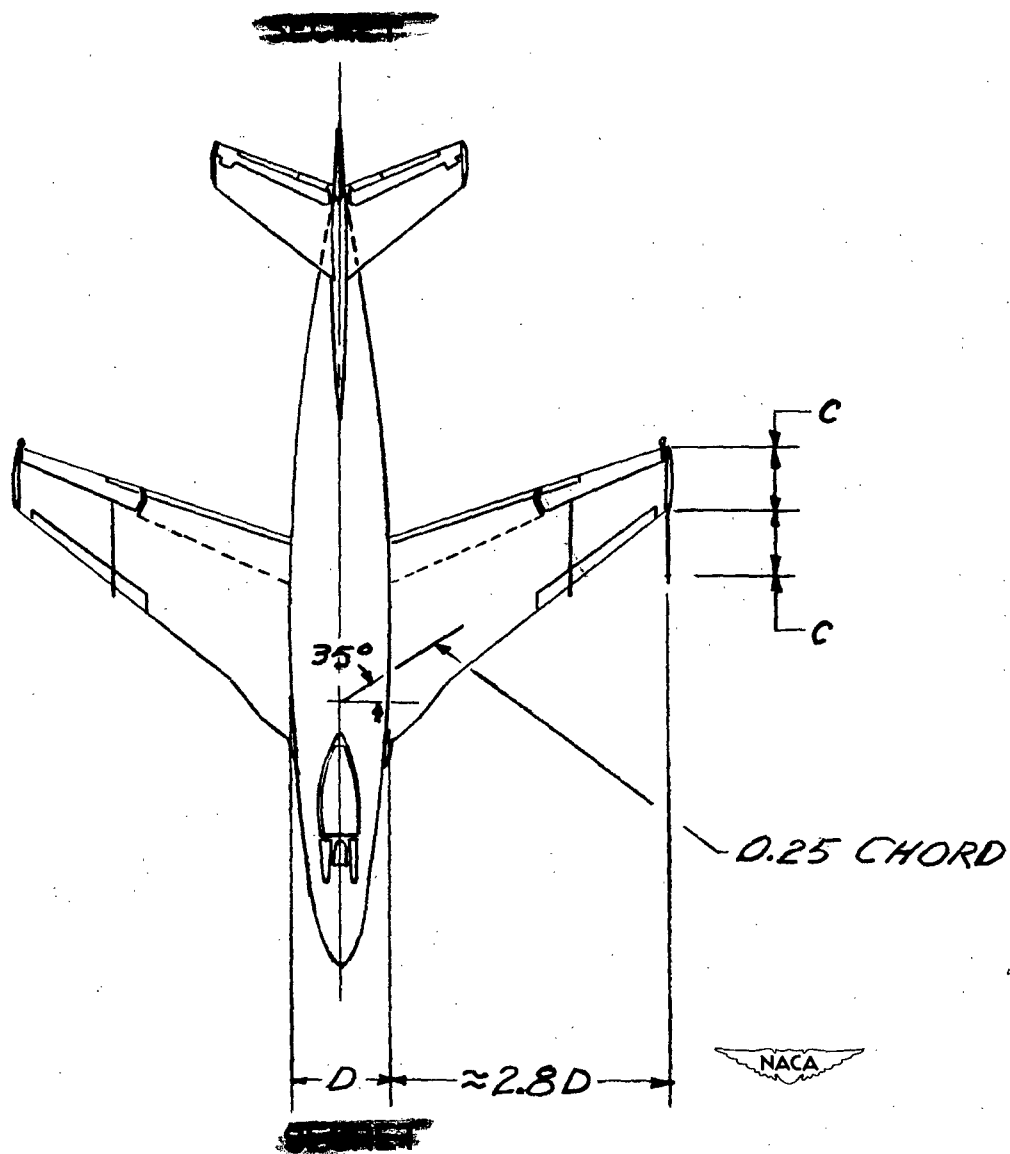


Figure 2.— Plan view of the McDonnell XF-88 airplane showing location of wing-tip-boom pitot-static head.

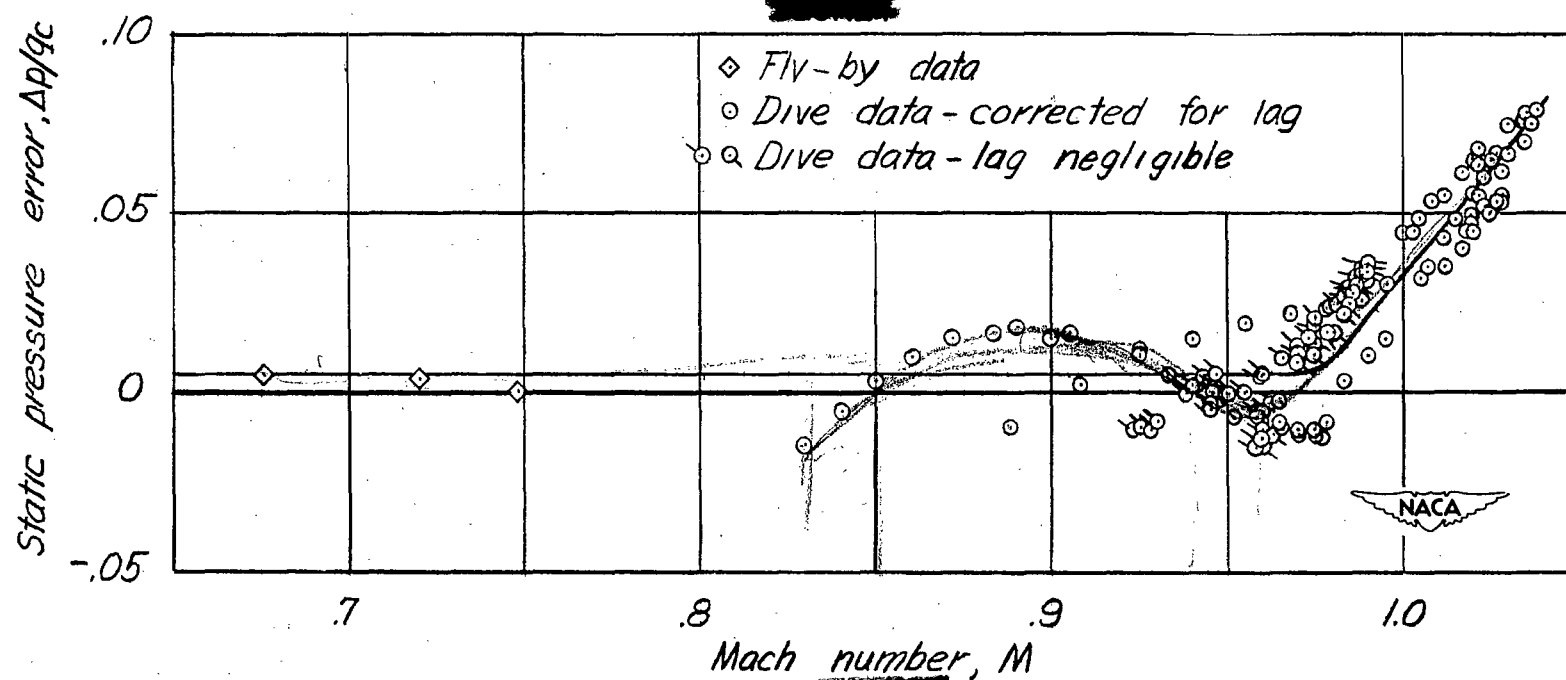


Figure 3.- The variation with Mach number of the static-pressure error of the wing-tip-boom airspeed installation of the XF-88 airplane.

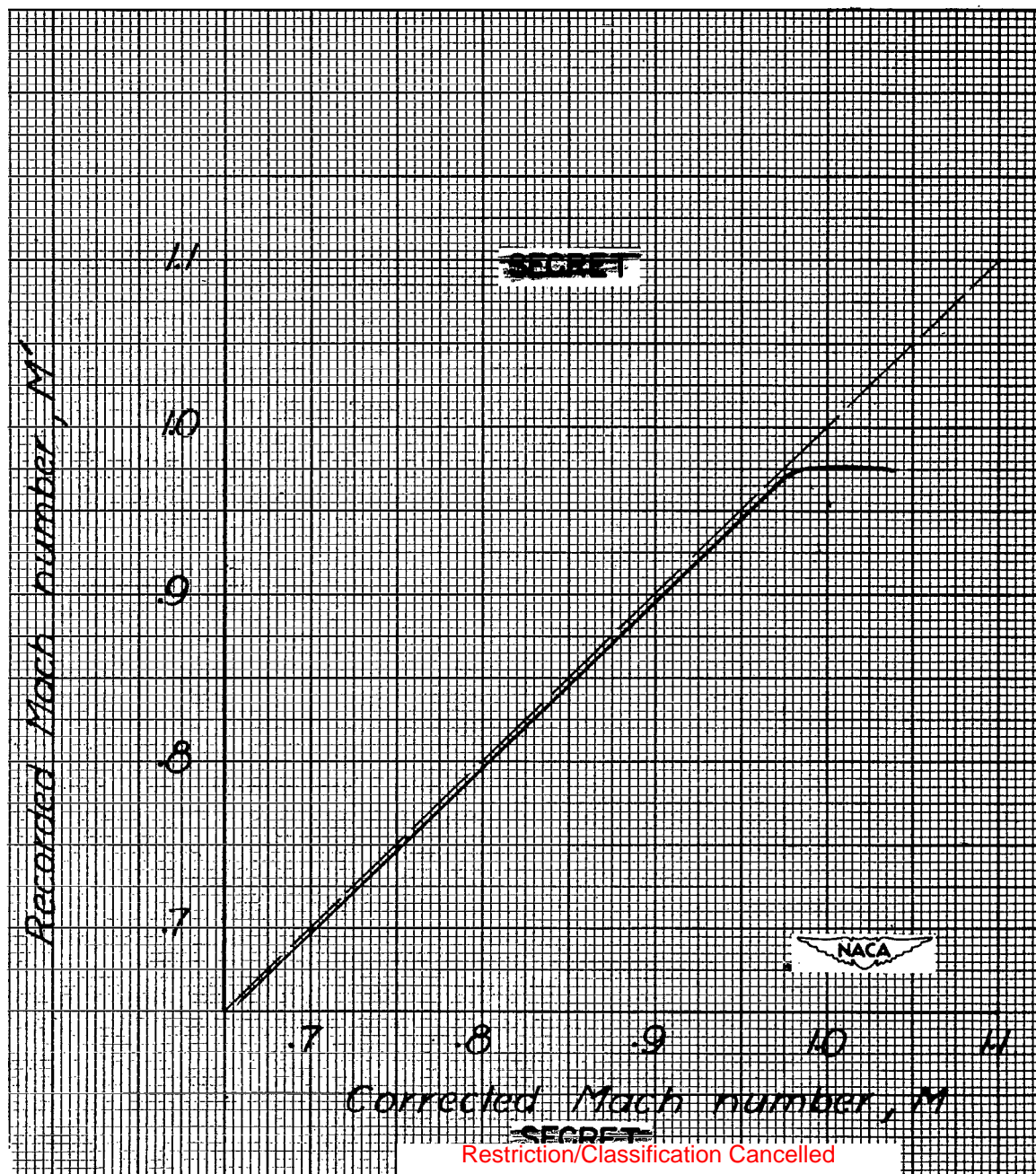


Figure 4.— The variation of the recorded Mach number with corrected Mach number for the wing-tip-boom airspeed installation of the XF-88 airplane.

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